

ResearchOnline@ND

University of Notre Dame Australia
ResearchOnline@ND

Education Papers and Journal Articles

School of Education

2015

Strengthening pre-service teachers' mathematical content knowledge

Gregory Hine

University of Notre Dame Australia, Gregory.Hine@nd.edu.au

Follow this and additional works at: http://researchonline.nd.edu.au/edu_article



Part of the [Education Commons](#)

This article was originally published as:

Hine, G. (2015). Strengthening pre-service teachers' mathematical content knowledge. *Journal of University Teaching & Learning Practice*, 12 (4).

Original article available here:

<http://ro.uow.edu.au/jutlp/vol12/iss4/5>

This article is posted on ResearchOnline@ND at

http://researchonline.nd.edu.au/edu_article/158. For more information,
please contact researchonline@nd.edu.au.



This is the author's post-print copy of the article published as:

Hine, Gregory (2015), Strengthening pre-service teachers' mathematical content knowledge.
Journal of University Teaching and Learning Practice, 12(4). Available:
<http://ro.uow.edu.au/jutlp/vol12/iss4/5/>

Strengthening Pre-Service Teachers' Mathematical Content Knowledge

Gregory S.C. Hine

The University of Notre Dame Australia

gregory.hine@nd.edu.au

Abstract

The tertiary training of pre-service teachers is pivotal in their professional preparation and formation as qualified educators. Multiple authors posit that teachers require a development of *pedagogical content knowledge*, or knowing a variety of ways to present mathematical content and to assist students to deepen their understanding (Chick, 2012; Shulman, 1987). Emerick, Hirsch and Berry (2003) argue that high quality teachers must possess appropriate *mathematical content knowledge*, and must also possess considerable background in communicating effectively to students. There are two aims of this educational research. The first is to investigate the self-perceptions of pre-service primary and secondary teachers enrolled in a mathematics education unit as they engage with and consolidate their mathematics content. The second aim is to explore how these pre-service teachers understand and perceive their 'readiness' to undertake such a task, based on their recent tertiary training. Data were collected from participants through the exercise of pre-unit (Phase 1) and post-unit (Phase 2) surveys. Following the completion of Phase 1, participant self-reflections indicated varying degrees of readiness to teach mathematics to Upper Primary and Lower Secondary students. Less than half of the sampled participants asserted that they felt confident in teaching mathematics, and almost all participants stressed the need to strengthen both their content knowledge and pedagogical content knowledge. This paper will discuss the key findings of Phase 1 in light of the extant literature on the preparation of pre-service mathematics teachers.

Introduction

Over the past two decades there has been a growing body of literature concerning the preparation of pre-service mathematics teachers. Research efforts have focused principally on approaches conducted by tertiary educators to adequately prepare pre-service teachers (PST) for the mathematics classroom. In particular, such efforts have emphasised the importance of *pedagogical content knowledge* (PCK) (Beswick & Goos, 2012; Shulman, 1986; 1987) and *mathematical content knowledge* (MCK) (Meany & Lange, 2012; Ponte & Chapman, 2008) in teacher preparation programs. Specifically, researchers have reported on ways to best support pre-service primary and secondary teachers' PCK (Aguirre, del Rosario Zavala & Katanyoutanant, 2012; Kennedy, Ball & McDiarmid, 1993) and MCK (Ma, 1999; Stohlmann, Moore, & Cramer, 2013), the effects of mathematical content units on PST (Matthews, Rech & Grandgenett, 2010), and the effects of mathematical pedagogy units on PST (Sowder, 2007). Other research has drawn attention to PST confidence levels and attitudes towards mathematics (Hamlett, 2009). Despite the extensive literature there is no consensus on how to adequately train PST of mathematics (Ball, Hill & Bass, 2003; Chapman, 2005). However, a growing number of scholars recommend teacher educators

focus their efforts on *mathematical knowledge for teaching* (MKT), or teaching both for procedural understanding and mathematical fluency (Delaney Ball, Hill, Schilling & Zopf, 2008).

Research Aims and Significance

There are two specific aims of this research project. The first is to investigate the self-perceptions of pre-service primary and secondary teachers enrolled in a mathematics education unit as they engage with and consolidate their mathematics content. The second aim is to explore how these pre-service teachers understand and perceive their 'readiness' to undertake such a task, based on their recent tertiary training. Both aims will be investigated during the two stages of the research project. The significance of this research lies in the belief that the unit *ED2315: Mathematical Learning for Early Adolescents* adequately prepares students' mathematical content knowledge in conjunction with their pedagogical content knowledge, and that research into this area can strengthen future efforts in preparing pre-service teachers. Specifically, the unit has the potential to influence the way pre-service mathematics teachers are professionally prepared to teach mathematical content in the classroom. This study seeks to build upon the extant literature by describing the self-perceptions of pre-service teachers preparing to teach mathematics to Upper Primary and Lower Secondary students.

Literature Review

Preparation of pre-service mathematics teachers

The preparation of elementary teachers in mathematics is an increasingly critical topic for teacher preparation programs (Matthews, Rech, & Grandgenett, 2010). Preparing teachers to teach mathematics effectively is one of the most urgent problems facing those who wish to improve students' learning (Morris, Hiebert, & Spitzer, 2009). Unfortunately it cannot be assumed that pre-service primary teachers entering Australian universities will be competent in mathematics (Hamlett, 2009). Hutchinson (1997) extends this notion, reporting how graduate teachers faced many problems which were largely due to their inadequate preparation in primary school mathematics content knowledge. According to Hungerford (1994) the Mathematical Association of America has registered a similar sentiment: "the mathematical preparation of elementary school teachers is perhaps the weakest link in our nation's entire system of mathematics education". More than 60 years ago, Glennon (1949) reported "those preparing to teach mathematics in the elementary grades understand approximately 50% of the computational processes taught in grades one to six" (cited in Rech, Hatzell & Stephens, 1993). Acknowledging that it is unrealistic to expect graduates of teacher preparation programs to enter the classroom as expert teachers, Hiebert, Morris, Berk and Jansen (2007) proposed that PST should acquire knowledge, skills, and dispositions that would enable them to study their teaching and gradually improve over time. After

the Australian Academy of Science identified mathematics as a critical skill for Australia's future, it was recommended that "all mathematics teachers in Australian schools have appropriate testing in the disciplines of mathematics and statistics" with "national accreditation standards for teachers of mathematics at all levels of schooling...and...appropriate programs to ensure that future teachers meet those standards" (Rubinstein, 2006, p. 15). Clear evidence indicates a strong relationship between teachers' mathematical content knowledge and their ability to teach well in classrooms (Ball, Hill & Bass, 2003; Chapman, 2005). Additionally, research in the United States has shown that the quality and the rigour of the mathematics curriculum are strongly correlated to the mathematical content knowledge of the teachers (Schmidt, 2002).

Pedagogical Content Knowledge (PCK)

Pedagogical content knowledge (PCK) is concerned with the most useful ways of representing and formulating mathematics that make it comprehensible to others (Beswick & Goos, 2012). PCK is also necessary for teachers to understand student misconceptions, to know how topics are organised and taught, as well as to influence the ability to adjust lessons catering for all learners (Shulman, 1987). Drawing upon the original ideas of Shulman (1986), many scholars have developed theoretically and empirically-based approaches to enhancing pedagogical approaches. For instance, Kennedy, Ball, and McDiarmid (1993) have suggested that during the teaching 'act', teachers draw upon knowledge of: learners, learning, pedagogy, the teacher's role, curriculum, and subject matter. In her work in teacher development, Grossman (1990) delineated four specific components of this specialised form of teaching knowledge:

1. An overarching knowledge and belief about teaching a subject at specific grade levels;
2. Knowledge of students' understandings, conceptions, and potential misunderstandings of particular topics of a subject;
3. Knowledge of curriculum and curricular materials, including horizontal and vertical directions within a subject;
4. Knowledge of the instructional strategies and representations for teaching particular topics.

In relation to mathematics teaching, Sowder (2007) argued that Grossman's delineation of PCK into four components "are helpful for those developing teacher education programs and professional development opportunities for mathematics teachers" (p. 164). Moreover, Aguirre, del Rosario Zavala & Katanyoutanant (2012) highlighted how mathematics PSTs require intellectual tools to support and extend PCK in rich and rigorous ways. One tool is through the exercise of reflective practice from a culturally responsive mathematics teaching perspective, whereby PSTs can develop robust forms of PCK to help them become effective mathematics teachers.

Mathematical Content Knowledge (MCK)

Mathematical content knowledge (MCK) has been described as a comprehensive understanding of mathematics which has breadth, depth, connectedness, and thoroughness (Ma, 1999). MCK has also

been described using a variety of terms, including: numeracy (Kemp & Hogan, 2009), quantitative literacy (Latiolais, Baloch & Loewi, 2003; Steen, 2001) and computational fluency (Flowers, 2003) as well as mathematical literacy (PISA). As articulated by PISA, mathematical literacy is viewed as “an individual’s capacity to identify and understand the role that mathematics plays in the world, to make well-founded mathematical judgments and to engage in mathematics in ways that meet the needs of that individual’s current and future life as a constructive, concerned and reflective citizen” (cited in Steen, 2001, p. 7). Mathematics understanding is understood as “the dynamic, constructed, and reconstructed process of sense making by the learner” and “learning to represent or communicate mathematical ideas or interpret mathematical representations through the use of language, diagrams, pictures, manipulatives, and other tools” (Heaton, 2000, p. 4). As such, it is important for PST to have a firm grasp of the mathematics they will teach in order to facilitate their students' explorations and investigations of mathematics concepts (Whittington, 2002).

Pre-service teachers' content knowledge is an essential focus for properly preparing teachers (Darling Hammond, 2000; Stohlmann, Moore, & Cramer, 2013). The AAMT *Standards for Excellence in Teaching Mathematics in Australian Schools* underscored the importance of teachers' MCK: “excellent teachers of mathematics have a sound, coherent knowledge of the mathematics appropriate to the student level they teach” (2002). However, no consensus exists on what mathematical content knowledge is needed to teach well (Ball et al., 2001). Research in the United States has shown that elementary teachers have room for improvement in robust content knowledge (Ball, Lubienski, & Mewborn, 2001; Ma, 1999). Several researchers have highlighted how many pre-service teachers—even those who have completed a major in mathematics (Bryan, 1999) - have gaps in their content knowledge or deficiencies in knowing how to apply and teach the mathematics addressed across the secondary school mathematics courses (Ball & Wilson, 1990; Mansfield, 1985). Without sound mathematical knowledge many pedagogical processes are of little benefit (Southwell & Penglase, 2005).

There is clear evidence on the relationship between teachers' MCK and their ability to teach well in classrooms (Ball, Hill & Bass, 2003; Chapman, 2005). Mathematical content courses are an effective way of enhancing the mathematical knowledge that elementary teachers might require for their own classroom instruction of mathematics (Matthews, Rech & Grandgenett, 2010). Moreover, such content courses can help new teachers to become more prepared to teach and represent the increasingly important discipline of mathematics to their students. Many states in the United States require prospective secondary mathematics teachers to pass the *Praxis II: Mathematics Content Knowledge* (10061) test before becoming certified to teach (Wilburne & Long, 2010). While this

test focusses on measuring PST undergraduate MCK, it does not assess their PCK, nor their understanding of the mathematics they will teach in a secondary classroom. Many mathematics educators, including Usiskin (2001), emphasise the need for PST to acquire content knowledge different from the kind they normally receive in university level instruction. Policy documents including *A Call For Change*, (Leitzel, 1991) and *The Mathematical Education of Teachers* (Conference Board of the Mathematical Sciences, 2001) recommend PST undertake courses that deepen and enhance current knowledge and conceptual understanding of the mathematics they will teach (Wilburne & Long, 2010). In support of this recommendation, teachers' MCK is not dependent on the number of university level courses, their grade point average, or their scores on a standardised test (Even, 1993; Ball, 1990). Furthermore, Monk (1994) found no correlation between the number of undergraduate mathematics courses taken by secondary mathematics teachers and their students' achievement. According to the Conference Board of Mathematical Sciences (2001), few university level mathematics courses actually address the mathematics pre-service secondary teachers will teach. Instead, teacher educators need to demonstrate the importance of well structured, content knowledge activities (Stohlmann, Moore & Cramer, 2013) to improve MCK without having a negative impact on PST confidence (Hamlett, 2009).

Mathematical Knowledge for Teaching (MKT)

Following Shulman's (1987) advocacy of knowledge categories for effective teaching, Delaney, Ball, Hill, Schilling, and Zopf (2008) have actively analysed and developed fundamental knowledge categories relevant to mathematics teachers. Instead of taking into account the multiple facets of PSTs' knowledge and beliefs, there appears to be a tendency among teacher educators to view PSTs as simply lacking particular knowledge (Delaney et al., 2008). Furthermore, although some PSTs are able to successfully solve mathematical problems, many are unable to explain the concepts and procedures they perform (Mewborn, 2001). Significantly, Ball, Hill, and Bass (2005) found a correlation between a teacher's mathematical knowledge and student achievement. However, these researchers concluded that teaching PSTs more content knowledge is not the best way to prepare teachers; rather, teaching for understanding is required. In addition to the content (i.e. the 'what' of mathematics), Delaney et al. (2008) asserted that teachers also need to know 'how' to teach Mathematics, and at the same time coined the term *mathematical knowledge for teaching* (MKT). Following research into MKT, certain scholars believe that implications for translating the content matter of mathematics into effective pedagogical practice are paramount in raising the profile of mathematics (Butterfield & Chinnappan, 2010). Others assert that MKT provides the most promising current answer to the longstanding question of what kind of content knowledge is needed to teach mathematics well (Morris, Hiebert & Spitzer, 2009). Various studies at the elementary

school level provide initial data linking teachers' MKT with the mathematical quality of instruction (Hill et al., 2008) and the level of students' achievement (Hill, Rowan & Ball, 2005). In support of developing MCK in PSTs, Ball, Thames, Bass, Sleep, Lewis and Phelps (2009) contended that teachers must be able to understand why particular content is taught and how the content should be developed. Additionally, teachers must be able to use their mathematical knowledge in teaching for identifying a range of solutions and mathematical connections when they are teaching students, planning lessons and evaluating students' work (Ball et al., 2009; Ball et al., 2008). To use MKT effectively, teachers must be able to access a wider range of knowledge such as procedural knowledge and fluency, concepts and connections (Ball, Hill & Bass, 2003).

Methodology

Context

At The University of Notre Dame Australia the unit *ED2315: Mathematical Learning for Early Adolescents* is offered to pre-service Primary and Secondary teachers completing a Bachelor of Education degree. Enrolled students can use the unit towards a specialisation or major in mathematics education. The unit is run over thirteen weeks for a total of 39 hours of contact time, and it is worth 25 credit points. During contact hours, pre-service teachers engage with middle school mathematical content (suitable both for Upper Primary and Lower Secondary students), receive exposure to best pedagogical approaches in teaching that content, review key curriculum and policy documents, and investigate best-practice approaches regarding planning, assessment, technology, and resources. Within the unit, students complete three assessments: An Analytical Paper (AP), Mid-Semester Examination (MSE) and a Final Summative Examination (FSE). The AP consists of two parts, where students must (i) complete 10 algebraic problems showing full working out and a final solution, and (ii) after choosing one of the problems completed in (i), write a 1 500-word analytical paper articulating best pedagogical approaches in teaching this problem to a middle school class. The MSE is a 75-minute assessment that requires students to demonstrate competency in the mathematical content covered in Weeks 1 - 7. The FSE is a 130-minute assessment consisting of two parts, where students must (i) write extended responses to two of five key topics in middle school mathematics, and (ii) demonstrate competency in the mathematical content covered in Weeks 7 - 13. The enrolment for this unit is approximately 40 students per semester.

Method

This study was interpretive in nature, and primarily used qualitative research methods to collect and analyse data about how pre-service teachers perceived their readiness to teach middle school mathematics. Participants recorded self-perceptions through three qualitative questions, and one seven-item, five-point, Likert scale question. The researcher used two online, qualitative surveys to collect data from research participants. In Stage 1 of the project, participants were asked to respond

to four research questions prior to commencing a thirteen-week tertiary unit based on mathematical content. During Stage 2 (immediately following the completion of this unit), the participants will be asked the same research questions. The research questions are included in Appendix 1.

Participants

Stage 1

The entire student population enrolled in the tertiary unit *ED2315: Mathematical Learning for Early Adolescents* was invited to participate in the research. Half of the students enrolled in this unit (20 of 40) comprised a self-selected sample for Stage 1 and completed a pre-unit survey. All students had the opportunity to review the ED2315 Unit Outline prior to giving informed consent to participate in the research. From the 20 participants, 6 were male and 14 were female. 12 participants were completing a BEd (Primary) degree, 4 a BEd (Secondary) degree, and 4 a BHPE degree. The Stage 1 Participants are tabulated in Table 1.

Table 1: Project Participants (Stage 1)

	Bachelor of Education (Primary)	Bachelor of Education (Secondary)	Bachelor of Health & Physical Education	Total
Male	1	2	3	6
Female	10	2	2	14
Total	11	4	5	20

Data Analysis

Qualitative data from the 20 pre-unit surveys were analysed and explored for common themes. When analysing these data, this project adhered to the framework and guidelines offered by Miles and Huberman (1994). This framework assisted the researcher in identifying relationships among social phenomena, based on the similarities and differences that connect these phenomena. The approach itself is comprised of three main components: data reduction, data display, and drawing and verifying conclusions. These components themselves involve three main operations: coding, memoing, and developing propositions. Codes, as Miles and Huberman (1994) explain, “are tags or labels for assigning units of meaning to the descriptive or inferential information compiled during a study” (p. 56). These codes were attached to the data gathered through qualitative surveys, and were selected from those data based on their meaning. The researcher then used memoing to synthesise coded data together so that they formed a recognisable cluster grounded within one general concept. The memoing process also captured the ongoing thoughts of the researcher as the process of coding took place. Lastly, as a study proceeds, there is a greater need to “formalise and systematise the researcher’s thinking into a coherent set of explanations” (Miles & Huberman, 1994, p. 75). For Stage

1 of this project, the researcher generated propositions about connected sets of statements made by participants, reflected on the findings, and drew preliminary conclusions from the study.

Presentation of Findings

Self-Perceptions of Readiness to Teach Mathematical Content

All of the participants (20 of 20) indicated the extent to which they felt ready to teach mathematical content to Upper Primary and Lower Secondary students. For the seven content topics available (Fractions, Decimals & Percentages; Algebra; Equations & Formulas; Perimeter, Area, Volume & Capacity; Calculating Probability; Using Statistics; Venn Diagrams) participants provided a Likert-scale rating from 1 - 5 (with 1 representing feeling least ready, and 5 representing feeling completely ready). Overall, participants shared they felt most ready to teach the topic *Perimeter, Area, Volume and Capacity* (mean = 3.85) and least ready to teach the topic *Using Statistics* (mean = 3.15). The mean score for each topic indicated a feeling of readiness among participants ($3.15 < \text{mean} < 3.85$), although not overwhelmingly so. These data are tabulated in Table 2.

Table 2: Self-Perceptions on Teaching Content

	1	2	3	4	5	Total	Mean	S.D.
Fractions, Decimals & Percentages	3	1	6	7	3	20	3.30	1.23
Algebra	1	2	8	7	2	20	3.35	0.96
Equations & Formulas	1	1	9	7	2	20	3.40	0.92
Perimeter, Area, Volume & Capacity	0	3	4	6	7	20	3.85	1.06
Calculating probability	3	2	5	5	5	20	3.35	1.35
Using Statistics	2	2	10	3	3	20	3.15	1.11
Venn Diagrams	2	4	4	4	6	20	3.40	1.36

Readiness to Teach Students

All participants (20 of 20) reported a variety of responses regarding their self-perceived readiness to teach mathematical content to Upper Primary and Lower Secondary students. Qualitative responses were classified by the researcher as: *Confident*, *Uncertain*, *Unconfident*, or *Undecided*. Eight of twenty participants communicated they felt confident to teach mathematical content. Various participant comments included “I feel completely ready”, “My core knowledge is strong”, “As I excelled in mathematics in school I believe I believe I am ready to teach any level of maths”, and “I completed the highest level of maths in Year 12. I also currently tutor high school students in mathematics”. Nine of twenty participants shared that they felt uncertain about teaching; for a majority of these responses participants articulated that they required further MCK, PCK and MKT, to varying degrees. To illustrate, one participant shared "I believe I have thorough content

knowledge and skills, but would need to work on how I deliver [those] to the class." Another participant stated that "I would be able to confidently extend a fair amount of knowledge to students, but cautious to receive questions and queries." A comparatively smaller number of participants intimated that they felt either unconfident (1 of 20) or undecided (2 of 20) to teach mathematics. One of these participants offered that "My mathematical involvements during school were very poor and I feel myself being very unconfident in this subject. Therefore, I think my readiness to teach the subject is very low until I know the content strongly enough to teach it."

Mathematical Content Knowledge Support Needed

A majority of participants (18 of 20) asserted that they required further MCK in order to adequately teach Upper Primary and Lower Secondary students. In addition, these participants identified particular Australian Curriculum strands where they felt additional MCK was needed. Specifically, over half of these participants (12 of 18) reported they required support in the strand *Number & Algebra*. One participant commented that support in *Number & Algebra* could include "Recapping[sic] a lot of formulas as most have been forgotten leaving myself stuck in situations; long expanded word questions; I need to get familiar with algebra again as I have forgotten plenty which leaves me unsure if I'm doing it correctly". A comparatively smaller proportion of participants reported that they needed further MCK from Australian Curriculum strands *Statistics & Probability* (4 of 18) and *Measurement & Geometry* (2 of 18). From the 2 of 20 who registered a feeling of 'unsure' one of them stated 'None yet, but I'm sure we'll find some'.

Getting the Most out of the Unit

All participants (20 of 20) predicted that completing the unit would positively contribute to their preparation as mathematics teachers. In particular, over half of the participants (14 of 20) mentioned that this unit would assist in both strengthening their MCK and PCK. One student was hopeful the unit would

Reinforce and clarify basic mathematics principles. Confirm that the way I do and think about them are correct and that I am not missing an easier or more certain method or understanding of them. I could probably do many of the examples at this level using a calculator, pen and paper but explaining the why of maths and the relationships between principles is something I hope to gain a clearer understanding of as well as the principles for teaching maths. The more times I work through it or have it explained the more ideas I hope to have for how to work through it clearly and logically with students.

Another student reinforced the link between PCK and MCK, stating that "I feel that it will provide me with pedagogy but also with the ability to calculate and solve mathematics problems effectively and accurately". In addition to such comments, a number of participants (4 of 20) shared that the unit would be effective in refreshing mathematical content. One participant stated "this unit will refresh my own prior knowledge from middle school and also provide me with some new content

knowledge, such as key terminology and strategies specific to the teaching of middle school mathematics”. Other participants (4 of 20) stressed that this unit would provide them with confidence to teach mathematics effectively. Here in one participant noted that “[the unit] will give me an understanding of the thinking processes during mathematics; it should give me an added confidence of delivering content to students”.

Discussion

The purpose of this research was to investigate the self-perceptions of pre-service primary and secondary teachers enrolled in a mathematics education unit as they engage with and consolidate their mathematics content. In addition to these self-perceptions, the researcher explored how the pre-service teachers understood and perceived their ‘readiness’ to teach middle school mathematics content, based on their recent tertiary training. The collected data from the initial surveys (Phase 1) were categorised under two conceptual themes. These themes are: *Valuable professional learning*, and *the need to strengthen mathematical content*. Both of these themes are now considered in light of the literature pertaining to pre-service, mathematics teacher development.

Valuable Professional Learning

All research participants (20 of 20) highlighted that the unit ED2315 would be valuable in their professional development as pre-service mathematics teachers. In addition, many participants were able to articulate the extent to which the unit would be useful to them in their professional roles. For instance, a majority of participants described how they felt the unit would assist them in strengthening their MCK, PCK, or MKT, or any combination of these three knowledge categories. Additional benefits included being ‘a good content refresher’, while others mentioned the unit helping to give them confidence in consolidating and teaching mathematics. This finding is consistent with literature underscoring the value of mathematics units for pre-service teachers (Butterfield & Chinnappan, 2010; Matthews, Rech & Grandgenett, 2010). Half of the Stage 1 participants (10 of 20) asserted that they felt either uncertain or unconfident in teaching upper primary or lower secondary mathematics, with another 2 participants sharing that they were undecided. This assertion, together with a majority of the surveyed population (18 of 20) reporting they feel they require further MCK, suggests that this unit is of considerable value to the preparation of undergraduate mathematics teachers. Even those participants who expressed a degree of confidence in their MCK (2 of 20) suggested the unit would strengthen their MKT or PCK or both. These self-reported participant claims concerning the value of the unit resonate closely with those of various scholars (Ball, Thames, Bass, Sleep, Lewis & Phelps, 2009; Whittington, 2002; Wilburne & Long, 2010).

The Need to Strengthen Mathematical Content Knowledge

As a corollary to research participants avowing the value of undertaking this unit, collected testimony frequently highlighted the self-reported need for pre-service teachers to consolidate their mathematical content knowledge. Half of the Stage 1 participants (10 of 20) asserted that they felt either uncertain or unconfident in teaching upper primary or lower secondary mathematics, with another 2 participants sharing that they were undecided. A majority of participants indicated that they felt least confident in their mathematical content knowledge first, then they required assistance in learning how to teach mathematics to students second. These assertions reinforce claims that educators must know how to apply and teach mathematics addressed in schools (Ball & Wilson, 1990; Mansfield, 1985), and that MCK is required for PCK to have any demonstrable impact (Southwell & Penglase, 2005). Over half those who admitted needing further assistance in strengthening their MCK (12 of 18) specified that the Australian Curriculum Strand they required assistance in was Number & Algebra. Although current literature suggests a need for mathematics teachers to improve their PCK, MKT and MCK overall, the research participants placed particular emphasis on the need to consolidate the MCK they require to teach students confidently and competently. Such emphasis accords with various scholars who posit that teachers require a firm grasp on MCK in order to facilitate student learning (Stohlmann, Moore & Cramer, 2013; Whittington, 2002; Wilburne & Long, 2010).

Conclusion

This paper explored the self-perceptions of pre-service primary and secondary teachers enrolled in a mathematics education unit as they prepared to engage with and consolidate their mathematics content. In addition, the self-reported understanding and perception of pre-service teachers' 'readiness' to undertake such a task was interrogated, based on their recent tertiary training. In addition to the body of literature already suggesting that pre-service mathematics teachers require additional support in developing their MCK, the testimony of the research participants reinforces that claim. At the same time the collected data from Phase 1 indicate the extent to which pre-service teachers believe taking a mathematical content unit will be valuable for their future professional roles. High value was ascribed to the acquisition of MCK, MKT, PCK, or any combination of these knowledge categories. In particular, all participants expressed a view that this unit will be valuable for them as they strengthen and consolidate their MCK, especially with key topics in the Australian Curriculum strand Number & Algebra.

List of References

Aguirre, J.M., del Rosario Zavala, M., & Katanyoutanant, T. (2012). Developing robust forms of pre-service teachers' pedagogical content knowledge through culturally responsive

mathematics teaching analysis. *Mathematics Teacher Education and Development*, 14(2), 113 - 136.

Australian Curriculum, Assessment & Reporting Authority (2015). *F- 10 mathematics curriculum*. Retrieved on 9/4/15 from <http://www.australiancurriculum.edu.au/mathematics/curriculum/f-10?layout=1>

Ball, D. (1990). The mathematical understandings that prospective teachers bring to teacher education. *The Elementary School Journal*, 90(4), 449 - 466.

Ball, D.L., Hill, H.C., & Bass, H. (2005). Knowing mathematics for teaching: Who knows mathematics well enough to teach third grade, and how can we decide? *American Educator*, 29(3), 14 - 46.

Ball, D. L., Lubienski, S., & Mewborn, D. (2001). Research on teaching mathematics: The unsolved problem of teachers' mathematical knowledge. In V. Richardson (Ed.), *Handbook of research on teaching* (4th ed.). New York: Macmillan.

Ball, D.L., Thames, M.H., Bass, H., Sleep, L., Lewis, J., & Phelps, G. (2009). A practice-based theory of mathematical knowledge for teaching. In M. Tzekaki, M. Kaldrimidou & H. Sakonidis (Eds.). *Proceedings of the 33rd Conference of the International Group for the Psychology of Mathematics Education* (Vol. 1, pp. 95 - 98). Thessaloniki, Greece.

Ball, D.L., Thames, M.H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education*, 59, 389 - 407.

Ball, D., & Wilson, S. (1990). *Knowing the subject and learning to teach it: Examining assumptions about becoming a mathematics teacher*. East Lansing, MI: Michigan State University, NCRTE.

Beswick, K., & Goos, M. (2012). Measuring pre-service teachers' knowledge for teaching mathematics. *Mathematics Teacher Education and Development*, 14(2), 70 - 90.

Boyd, D., Grossman, P., Lankford, H., Loeb, S., & Wyckoff, J. (2009). Teacher preparation and student achievement. *Educational Evaluation and Policy Analysis*, 31(4), 416-441.

Bryan, T.J. (1999). The conceptual knowledge of pre-service secondary mathematics teachers: How well do they know the subject matter they will teach? *Issues in the Undergraduate Mathematics of School Teachers: The Journal*, 1.

Butterfield, B., & Chinnappan, M. (2010). Walking the talk: Translation of mathematical content knowledge to practice. In L. Sparrow, B. Kissane & C. Hurst (Eds). *Proceedings of the 33rd Annual Conference of the Mathematical Education Research Group of Australasia*, Fremantle, WA.

Cavanagh, S. (2009). Majoring in math not always a classroom plus. *Education Week*, 29(13), 14-15.

Cavanagh, M., & Prescott, A. (2007). Professional experience in learning to teach secondary mathematics: Incorporating pre-service teachers into a community of practice. *Mathematics: Essential Research, Essential Practice*, (1), 182-191.

Chapman, O. (2005). Constructing pedagogical knowledge of problem solving: Preservice

mathematics teachers. In Chick, H.L. & Vincent, J.L. (Eds.), *Proceedings of the 29th Conference of the International Group for the Psychology of Mathematics Education*, 2, 225 - 232.

Chick, H. (2012). *Pedagogical content knowledge*. Paper presented at CEMENT Conference. The University of Tasmania: Launceston.

Darling-Hammond, L., & Bransford, J. (2005). *Preparing teachers for a changing world*. San Francisco: Jossey Bass.

Delaney, S., Ball, D., Hill, H.C., Schilling, S.G., & Zopf, D. (2008). Mathematical knowledge for teaching: Adapting U.S. measures for use in Ireland. *Journal of Mathematics Teacher Education*, 11(3), 171 - 197.

Emerick, S., Hirsch, E., & Berry, B. (2003). *Unfulfilled promise: ensuring high quality teachers for our nation's students*. Retrieved from <http://www.teachingquality.org>

Even, R. (1993). Subject-matter knowledge and pedagogical content knowledge: Prospective secondary teachers and the function concept. *Journal for Research in Mathematics Education*, 24(2), 94 - 116.

Goos, M. (Spring, 2006). License to thrill or live and let die? *Principal Matters*, 6-8.

Grossman, P. (1990). *The making of a teacher: Teacher knowledge and teacher education*. New York: Teachers College Press.

Hamlett, B. (2009). Supporting pre-service primary teachers to improve their mathematics content knowledge. *eCulture*, 2, 76-82.

Heaton, R. (2000). *Teaching mathematics to the new standards: Relearning the dance*. New York: Teachers College Press.

Hiebert, J., Morris, A.K., Berk, D., & Jansen, A. (2007). Preparing teachers to learn from teaching. *Journal of Teacher Education*, 58, 47 - 61.

Hill, H.C., Blunk, M.L., Charalambous, C.Y., Lewis, J.M., Phelps, G.C., Sleep, L. (2008). Mathematical knowledge for teaching and the mathematical quality of instruction: An exploratory study. *Cognition and Instruction*, 26, 430 - 511.

Hill, H.C., Rowan, B., & Ball, D.L. (2005). Effects of teachers' mathematical knowledge for teaching on student achievement. *American Educational Research Journal*, 42, 371 - 406.

Hungerford, T.W. (1994). Future elementary teachers: The neglected constituency. *The American Mathematical Monthly*, 101(1), 15 - 21.

Hutchinson, L. (1997). Learning for teaching: A case of constructing the bridge between subject matter knowledge and pedagogical content knowledge (Research Report). Wyoming: The University of Wyoming.

Kennedy, M.M., Ball, D.L., & McDiarmid, G.W. (1993). A study package for examining and tracking changes in teachers' knowledge. East Lansing, MI: National Center for Research on Teacher Learning.

- Kemp, M., & Hogan, J. (2000). Planning for an emphasis on numeracy in the curriculum. Retrieved from http://www.thenetwork.sa.edu.au/pages/educators/articles_papers_index/
- Latiolais, M.P., Collins, A., Baloch, Z., & Loewi, D. (2003). Assessing quantitative literacy needs across the university. *Portland State University Faculty Focus*, 14(1).
- Leitzel, J.R. (1991). *A call for change: Recommendations for the mathematical preparation of teachers of mathematics*. Washington, DC: Mathematical Association of America.
- Ma, L. (1999). Knowing and teaching elementary mathematics. Teachers' understanding of fundamental mathematics in China and the United States. Mahwah, New Jersey: Lawrence Erlbaum Associates Inc.
- Mansfield, H. (1985). Points, lines, and their representations. *For the Learning of Mathematics*, 5(3), 2 - 6.
- Matthews, M., Rech, J., & Grandgenett, N. (2010). The impact of content courses on pre-service elementary teachers' mathematical content knowledge. *IUMPST: The Journal*, 1, 1-11.
- Meany, T., & Lange, T. (2012). Knowing mathematics to be a teacher. *Mathematics Teacher Education and Development*, 14(2), 50-69.
- Mewborn, D. (2001). Teachers content knowledge, teacher education, and their effects on the preparation of elementary teachers. *United States Mathematics Education research Journal*, 3, 28 - 36.
- Miller, K.W., & Davidson, D.M. (2006). What makes a secondary school science and/or mathematics teacher "highly qualified"? *Science Educator*, 15(1), 56-59.
- Monk, D. (1994). *Subject area preparation of secondary mathematics and science teachers and student achievement*. *Economics of Education Review*, 13(2), 125 - 145.
- Morris, A.K., Hiebert, J., & Spitzer, S.M. (2009). Mathematical knowledge for teaching in planning and evaluating instruction: What can pre-service teachers learn? *Journal for Research in Mathematics Education*, 40(5), 491-529.
- Norton, S. (2010). How deeply and how well? How ready to teach mathematics after a one-year program? *Mathematics Education and Special Education*, 12(1), 65-84.
- Osana, P., Lacroix, G., Tucker, B., & Desrosiers, C. (2006). The role of content knowledge and problem features on pre-service teachers' appraisal of elementary mathematics tasks. *Journal of Mathematics Education*, 9, 347-380.
- Ponte, J.P., & Chapman, O. (2008). Preservice mathematics teachers' knowledge and development. In L.D. English (Ed.), *Handbook of International Research in Mathematics Education* (pp. 233-261). New York: Routledge.
- Rech, J., Hartzell, J., & Stephens, L. (1993). Comparisons of mathematical competences and attitudes of elementary mathematics majors with established norms of a general college population. *School Science and Mathematics*, 93(3), 141 - 144.
- Rubinstein, H. (2006). Mathematics and statistics: Critical skills for Australia's future. Key findings

and recommendations of the National Strategic Review of Mathematical Sciences Research in Australia. Melbourne: Australian Academy of Science.

Schmidt, W. (2002). The benefit to subject-matter knowledge. *American Educator*, 26(2), 18 - 22.

Shulman, L. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, 15(2), 4 - 14.

Shulman, L. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, 57(1), 1 - 22.

Southwell, B., & Penglase, M. (2005). Mathematical knowledge of pre-service primary teachers. In Chick, H.L., & Vincent, J. L. (Eds). *Proceedings of the 29th Conference of the International Group for the Psychology of Mathematics Education*. Vol. 4, 209-216. Melbourne, PME.

Steen, L.A. (2001). Mathematics and democracy: The case for quantitative literacy: National Council on Education and the Disciplines, Woodrow Wilson National Fellowship Foundation.

Stohlmann, M.S., Moore, T.J., & Cramer, K. (2013). Preservice elementary teachers' mathematical content knowledge from an integrated STEM modelling activity. *Journal of Mathematical Modelling and Application*, 1(8), 18-31.

Toh, T.L. Kaur, B., & Koay, P.L. (2013). Singapore Pre-service Secondary Mathematics Teachers' Content Knowledge: Findings from an International Comparative Survey. *International Journal for Mathematics Teaching and Learning*, 1, 1 - 22.

Usiskin, Z. (2001). Teachers' mathematics: A collection of content deserving to be a field. *The Mathematics Educator*, 6(1), 85 - 97.

Appendices

Appendix 1: Pre-Unit Survey

1. How ready do you feel to teach the following topics? Complete each item by selecting a number (1 indicates the least ready, 5 indicates the most ready).

- (a) Fractions, Decimals, Percentages
- (b) Algebra
- (c) Equations and Formulas
- (d) Perimeter, Area, Volume, Capacity
- (e) Calculating Probability
- (f) Using Statistics
- (g) Venn Diagrams

2. Describe your readiness to teach mathematics to Upper Primary/Lower Secondary students in terms of the mathematical content knowledge and skills you currently possess.

3. In what area(s) of mathematical content knowledge do you feel you require further learning?

4. How do you feel this unit will contribute to your grasp of middle school mathematical content?